Signal Processing Improvements for Interactive Localization with a Man/AUV-Portable Tensor Magnetic Gradiometer

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LONG TERM GOAL

Our long-term goal is to provide a robust suite of algorithms capable of performing real-time localization of both isolated and grouped ferromagnetic targets. It is intended that these algorithms be applicable to any tensor magnetic gradiometer system used for surface or subsurface platforms. These algorithms will be most robust when used in conjunction with conventional navigational systems, but will be provided with a self- navigating capability that exploits the magnetic fields and gradients of the sources being localized.

OBJECTIVES

Perform a thorough analysis of the motion compensation process used to allow tensor fluxgate gradiometers to be moved about in the presence of the earth's magnetic field. Incorporate the results into interactive real time gradient motion compensation software running on a PC platform.

Upgrade tensor fluxgate gradiometer localization software to make it more interactive and self-contained. Generalize it to incorporate GPS positional information, when available, and to allow real time data input from either GPIB/VXI interfaces or Serial interfaces.

Develop software to use angular rate sensor data to correct for rotational changes in the gradient tensor measured by a moving gradiometer in the presence of magnetic targets.

APPROACH

The technology used in both fluxgate gradiometry and High Critical Temperature superconducting gradiometry uses a field reference sensor and feedback coils to reduce the main field at the sensors in the gradiometer array. Work with the superconducting sensors [1] suggests that motion noise compensation is improved if both the reference sensor and a sensor subject to feedback are used as motion compensation references. We have investigated multiple input-multiple output time domain lagged filter techniques for gradiometer motion compensation.

The VEE programming environment, originally developed by Hewlett-Packard, and now supported by Agilent Technologies, provides a rich software environment allowing real time instrument control and data acquisition, as well as the incorporation of arbitrarily complex algorithms written in other languages and converted to Windows Dynamic Link Libraries (DLLs). This is the software environment we have chosen for gradiometer signal processing algorithm development and execution.

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All of our software development has taken advantage of an extensive set of data collected under the 1997-98 SOCOM and 1999 ONR sponsored Tensor Fluxgate Gradiometer Development program.

WORK COMPLETED

We have done an exhaustive analysis of time domain multiple input-multiple output motion compensation using lagged filter weights. We have incorporated the new motion compensation algorithm into upgraded interactive localization software, and have exercised the software against numerous data sets. We have begun work on gradient tensor rotation noise correction with angular rate sensor data, but do not expect to complete this work.

RESULTS

Motion Compensation:

We have found that, as long as both the reference magnetometer and any one of the gradiometer array magnetometers subject to feedback are used, very little improvement is gained if more than one sample lag is used. This means that a fixed-parameter model is still acceptable, as long as it computes balance and eddy current coefficients for both the reference magnetometer components and the components of one of the magnetometers experiencing feedback, for a total of 12 parameters for each gradient tensor component. We have written a motion compensation algorithm ***fulmocom.dll*** to perform this process. Figure 1 shows the graphical VEE program that implements this DLL, shown in dark blue, and shows the residual rms noise, for all six channels of the Phase I RTG sensor [2], for a vigorous motion experiment with the sensor mounted on a shake table. The residual noises are generally close to, or below the stationary sensor noise specification.

Interactive Localization Software:

The latest version of localization software is a VEE program that uses the first part of a data run to establish motion compensation parameters for that run with an algorithm ***baleddy.dll***, and then compensates subsequent data for that run on-the-fly, using an algorithm ***mocomfly.dll***. The resulting data is passed to the interactive localization algorithm ***simptrks.dll***, which establishes the bearing vector to the target. The program structure is much too complicated to show in a figure. The results obtained with the program for a run past a large ordnance shell at a lateral distance of 9 feet to the right of, and 3 feet below the plane of the sensor are shown in Figure 2. The sensor is carried in the positive y direction, with x positive up, and z positive to the left. Relative to the operator, the target moves from positive to negative y, with negative x and z position. The anomalous behavior seen toward the end of the run is due to magnetic trash (evident in the data) near the track of the sensor. The bearing vector tends to dip toward the second object, but the nonlinear processing scheme becomes somewhat confused.

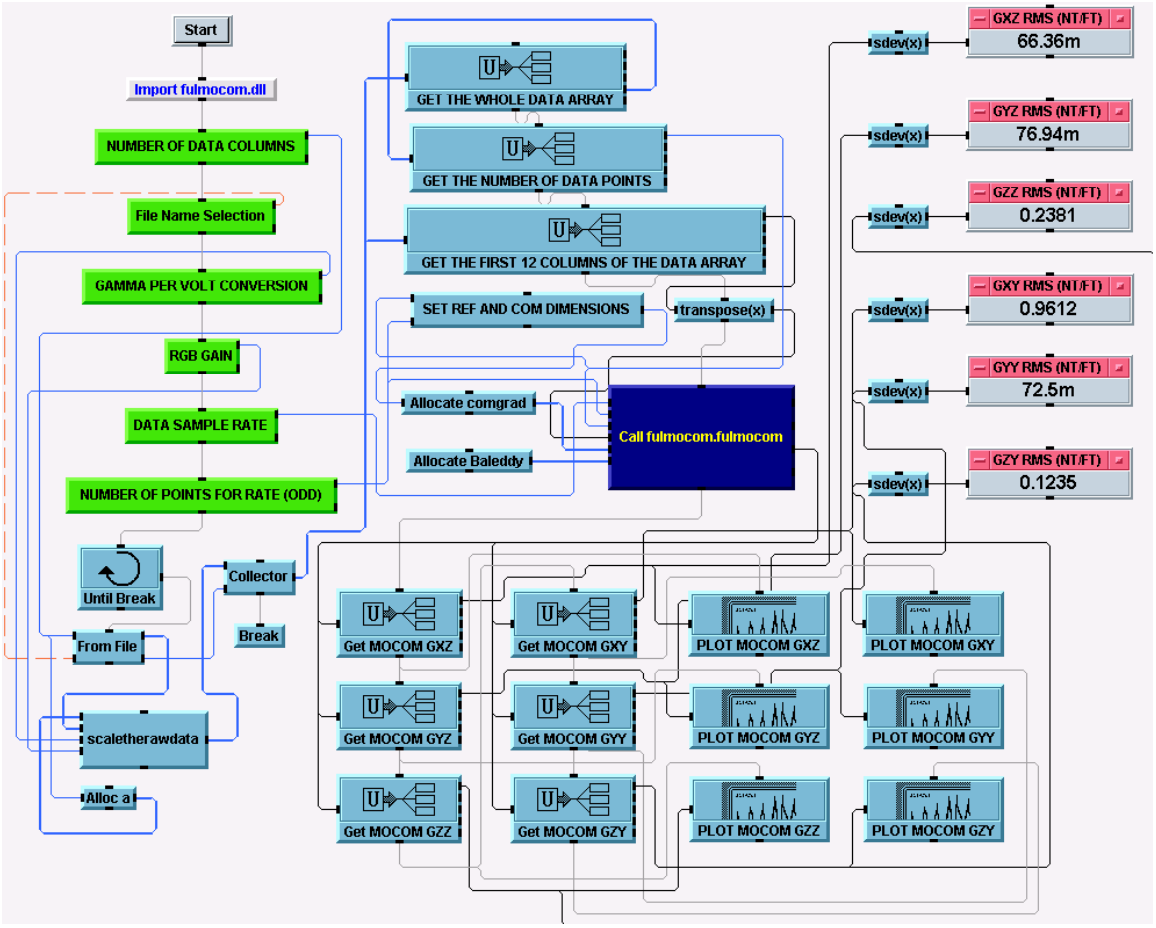

Figure 1. VEE program for six inputs-six-outputs motion compensation.

Serial Interfacing:

We have received the Phase II RTG gradiometer [2], which processes and presents data as 72 byte words (24 channels, 3 bytes~20 bits plus extended sign) at a rate of 100 hz. We have written VEE software to access this data with a notebook computer, unstack and restore the floating point data, and do a preliminary evaluation of sensor performance.

IMPACT/APPLICATIONS

We have already used the latest software to provide critical support to an FY 2000 new start (see below), we have used variants of the software to support the analysis of data for the ONR sponsored Littoral Sea Mine program, and we will continue to use and improve the software under these programs in FY 2001.

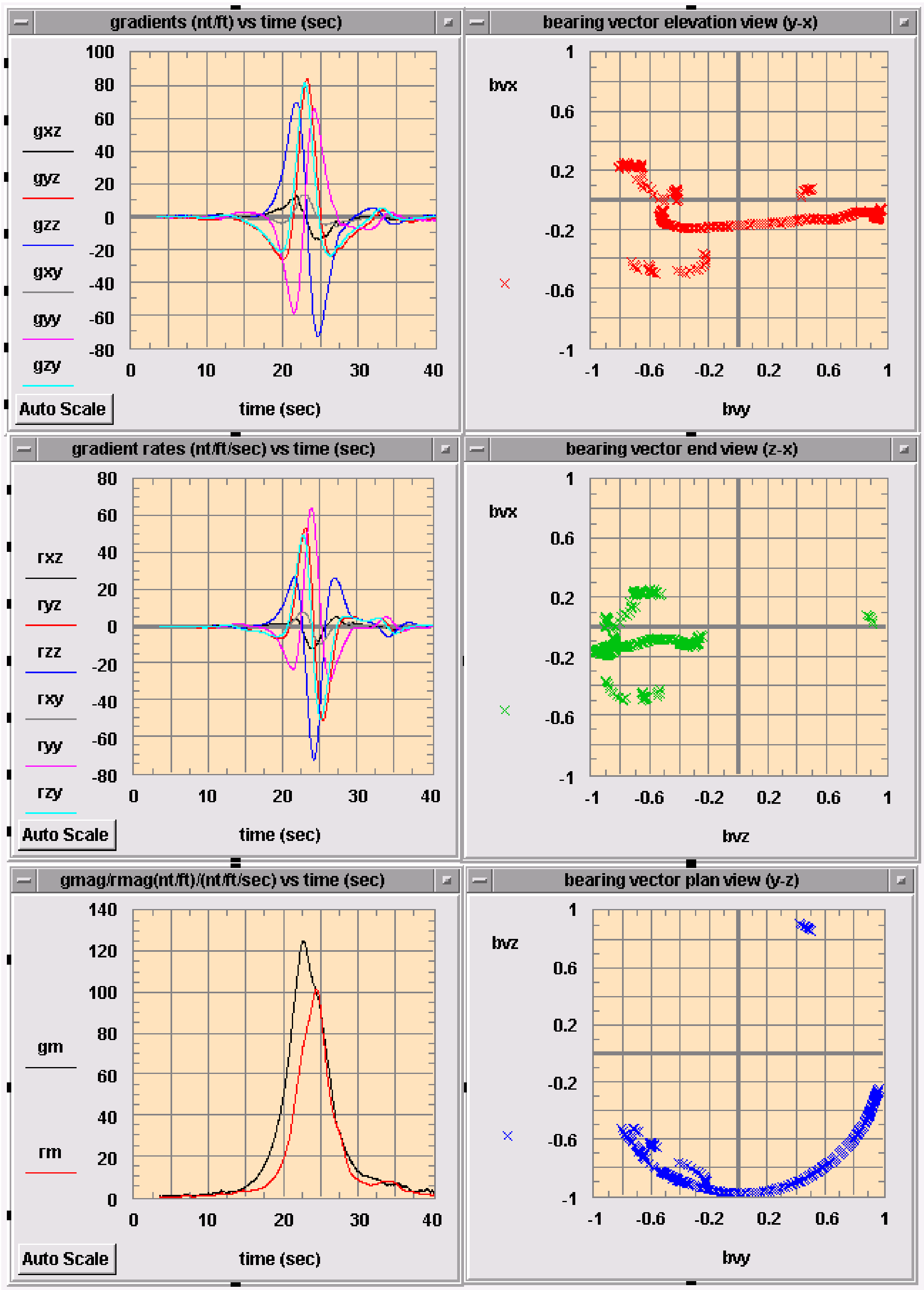

Figure 2. Gradient, gradient rates, and bearing vector for large ordnance shell.

TRANSITIONS

None.

RELATED PROJECTS

Magnetic Sensing for VSW Mine Reconnaissance (new start) #N10001400WX21033

Magnetic Sensors Project #N10001400WX20563

REFERENCES

1. John T. Bono, private communication (theorist, Magnetic Sensors Project)

2. G. I. Allen and W. M. Wynn, "Tensor Fluxgate Gradiometer Development", ONR year end report, FY 1999 (#N0001498WX30244) (see enclosed references in this report).

PUBLICATIONS

W. M. Wynn, "Interactive Localization of Stationary Magnetic Targets with a Man-Portable Tensor Fluxgate Gradiometer", in Military Magnetic and Electric Field Sensors Workshop, Applied Physics Laboratory/Johns Hopkins University, October 17-19, 2000